CALIFORNIA AGRICULTURAL EXPERIMENT STATION

INVESTIGATIONS OF THE FLOR SHERRY PROCESS

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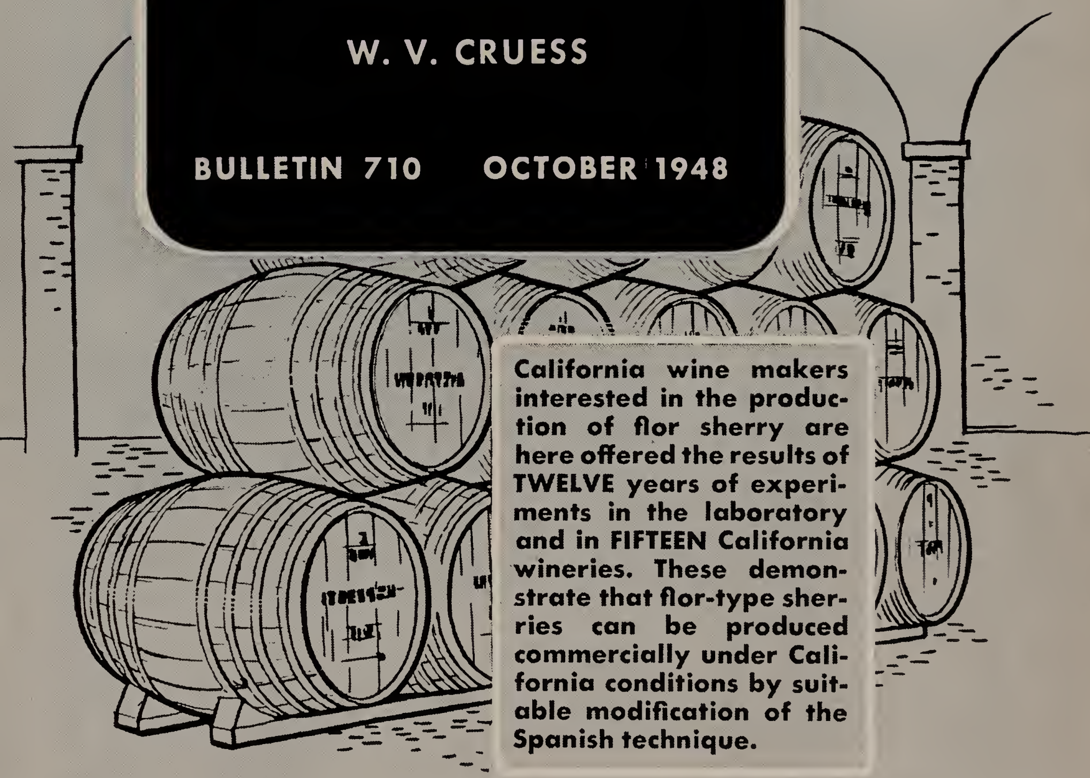

California wine makers interested in the production of flor sherry are here offered the results of TWELVE years of experiments in the laboratory and in FIFTEEN California wineries. These demonstrate that flor-type sherries can be produced commercially under California conditions by suitable modification of the Spanish technique.

THE COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA · BERKELEY

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INVESTIGATIONS OF THE FLOR SHERRY PROCESS

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SPANISH or flor sherries differ from other sherries in their distinctive bouquet and flavor. To obtain these characteristic qualities, Spanish sherries are fermented and aged by a unique process involving the use of an unusual group of film-forming yeasts called flor yeasts. While not all Spanish sherries are made by the flor process, most of those met in the trade possess the flor bouquet and flavor, because the wine shipped from Spain is nearly always a blend containing some flor sherry.

Equally important to the making of flor sherries is the solera system, a complicated method of aging the wine which provides for progressive, fractional blending. Both the flor yeasts and the principle of the solera system of aging are adaptable for use in California wineries.

SPANISH SHERRY MAKING

SHERRY derives its name from the city of Jerez de la Frontera in the province of Cadiz in southern Spain. According to Spanish law, only wines made in this city and in a small specified area surrounding it are entitled to the name *Jerez, Xerez,* or sherry. The most popular Spanish sherries today are very pale to light amber in color, and dry, or nearly so.

CLASSES OF SPANISH SHERRY

In their natural, unblended condition, Spanish sherries fall into two main classes, FINO and OLOROSO, each having several sub-types.

Fino-type wines are made with the use of flor yeast, *oloroso* without it. Blending of the two types is sometimes done.

Some *fino* wines are bottled as such after suitable blending and finishing, and are available under brand names. They are pale to very pale in color, dry or nearly so, and of pronounced, rather pungent bouquet and flavor, with a powerful, characteristic, and lasting after-taste.

Manzanilla wines are *fino*-type wines made at Sanlúcar de Barrameda, about 18 miles northwest of Jerez de la Frontera. Grapes for *manzanilla* are grown on sandy soil and have a lower sugar content than those of Jerez. These wines are very pale, and are best when very dry. For export, brandy is added.

Amontillado, a *fino,* is probably the most famous of all types of the wines of Jerez. While it is basically a *fino* sub-type, it is often considered in a category of its own. In its early years it is aged under flor film as a *fino*. Because of increase in alcohol content, naturally or by fortification, the flor yeast is eventually no longer able to grow, and continued aging without the flor film gives *amontillado* its characteristic deep color and the "bite" or sharpness greatly appreciated by connoisseurs.

If held in wood a sufficient time, *amontillado* wines become dark brown in color, lose most or all of their *fino* character, and become distinctly bitter. They are then known as *vinos viejos,* or old wines, which are of great value in blending.

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Oloroso type wines, because of their naturally high alcohol content (16 per cent or above by volume), or because of fortification of the new wine, develop without flor film. They are full-bodied, full-flavored wines before blending, and lack the peculiar pungency of flavor and bouquet of the *finos*. They are darker in color than most wines of the *fino* class. However, very old *amontillado* and very old *oloroso* wines resemble each other markedly in color, bitterness and lack of *fino* pungency. According to de Bobadilla (1947), alcohol content of *oloroso* wines is raised to about 18 per cent before they enter the solera.

Fig. 1. A good vine of Palomino grapes, Jerez de la Frontera. (Courtesy of Pedro Domecq.)

For blending with wines of the *fino* and *oloroso* groups, several other classes of wines are made in Jerez. One of these is *vino de color*, which, de Castella (1926) states, is made by adding *arrope*, a dark brown, caramelized grape concentrate, to fresh or fermenting must, and fermenting out nearly all of the sugar, or by adding *arrope* to the wine. This wine is very dark in color, and bitter and caramelized in flavor. When sufficiently aged it is very useful in blending.

Pedro Ximénèz (or Pedro Jimenez or P.X.) is a very sweet blending wine made by fermentation of the very sweet must of Pedro Ximénèz grapes that have been partially dried in the sun. It is used to impart sweetness to other sherries.

Dulce apogado and *mistela* are similar to California Angelica and are made by fortifying unfermented or slightly fermented white musts.

THE VINTAGE IN JEREZ

Herein is described what grapes are grown and how they are handled in Jerez, in an account drawn mainly from the writings of de Castella (1909, 1926), Gonzales-Gordon (1935), Bobadilla (1940, 1943, 1944), and personal communications of Dr. M. A. Amerine and others.

The Palomino is the grape most used for sherry in Jerez.

This variety, also called *Listan,* is used to make wines of both *fino* and *oloroso* types. It is grown in California as Napa Golden Chasselas, as well as Palomino, and in Australia as Sweet Water.

Another white variety, Pedro Ximénèz, is used for sweet blending wine. Other less important varieties are *Mantuo de Pilas, Mantuo Castellano, Albillo, Perrano,* and *Cañocazo.*

A white calcareous soil produces the best grapes for sherry. This soil, of Miocene age, is known locally as *albariza,* and is of exceptionally high calcium content. Vines grown on it give a low yield, but produce grapes of the highest quality. *Barros* soils are more extensive, and are a mixture of clay with limestone soil, or with sand. *Barros* soils are said to produce much heavier crops than do the *albariza* soils. *Arenas* soils are very sandy, and in the Sanlúcar district produce Palomino grapes used in making *manzanilla* wines. Vines in the Jerez area are planted close together, pruned very low, and grown without irrigation.

Harvesting begins in September and continues to mid-October.

The grapes are cut at desired maturity (after the main stems have become brown) with short-bladed knives, rather than with clippers, and are placed in small shallow wooden boxes with handles, known as *tinetos,* or in small baskets. The *tineto* holds about one *arroba* (about 25 pounds).

Approximately 60 *arrobas* of grapes yield sufficient must for one *bota* (butt or cask), the customary container for fermentation of must and aging of wine.

The vineyard is picked over more than once if the grapes are not all of the desired maturity. For *fino* wines the optimum Baumé degree is 14°–15°, or about 26°–28° Balling or Brix, and for *oloroso* wines, above 15° Bé, or above 28.5° Balling or Brix.

Grapes are sun-dried for 24 hours for FINOS, and several days for OLOROSOS.

The small boxes or baskets of grapes are transported by mule back in special frames, or by ox cart or by truck to the *almijar,* an open courtyard next to the *casa de la gares* (crushing house). The grapes are spread on small esparto grass mats in the sun, the contents of one or more boxes or baskets to each mat. At night the grapes are sometimes covered to prevent deposition of dew. Grapes for *fino* wines lose very little of their water content, and are left in the *almijar* only twenty-four hours or less. Those for *oloroso* wines are usually left several days. Pedro Ximénèz grapes are left up to two weeks, during which time they become partially "raisined." The must often attains 40° Balling or Brix, or more, and a raisin-like flavor and color. This trend is in accord with the adoption of modern equipment for some of the other operations such as filtration, pumping and others. Nevertheless, much more hand labor is still used than in California wineries.

Crushing is done by men shod with special shoes for treading, or by metal rollers, or sometimes by both.

The grapes are emptied into a shallow rectangular wooden vat, called a *lagar,* about 12 feet square and 1½ feet in depth, and elevated above the crushing floor. Each crushing house contains several of these vats, in each of which enough grapes are crushed to furnish free run and first pressing wine for one butt, about 130 U. S. gallons.

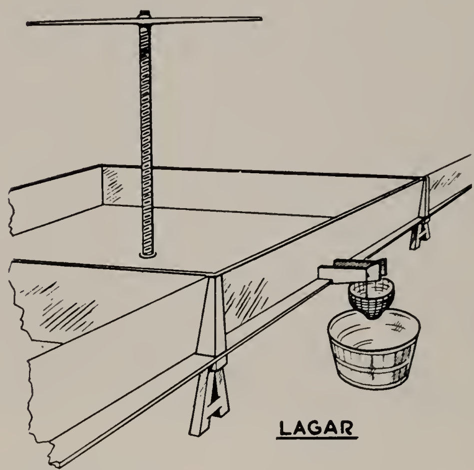

Fig. 2. Crushing and pressing trough, or lagar. (Pedro Domecq.)

Men equipped with special heavy-soled shoes may tread the grapes. Crushing in this manner is said by some to be better than the use of metal rolls, because it extracts less tannin and coarseness from the stems and skins. This coarseness (*basto* flavor) is to be avoided as the greatest enemy of quality in Spanish sherries, according to Gonzales-Gordon (1935). However, use of roller crushers is now common but may be followed by treading as described above. Some wineries omit treading and use presses directly after crushing by metal rolls. According to Dr. M. A. Amerine (1948) an increasing number of Spanish wineries are adopting this procedure.

Fig. 3. Grapes sun-drying before a crushing shed in Jerez. Tower of Macharnudo Castle in background. (Pedro Domecq.)

Crude plaster of Paris is added to the crushed grapes.

Plastering is a customary feature of the crushing process of Jerez de la Frontera. The crushed grapes are sprinkled with *yeso,* a crude plaster of Paris made by heating the naturally-occurring gypsum of this area to a high temperature. The amount of *yeso* added varies according to the district, the shipper, and the method of pressing, according to Amerine (1948). De Castella (1926), reports that it usually ranges from about 12 to 15 pounds per ton, or 6 to 7.5 grams per 1000 grams. Gonzales-Gordon (1935) states that it averages about 1.5 grams per 1000 grams of crushed grapes, or about 3 pounds per ton; and Marcilla (1946) recommends that not more than 12.5 grams of *yeso* per 1000 grams, 25 pounds per ton, be used.

The principal purpose of plastering is to increase the active acidity of the must, i.e., to lower its pH and to facilitate pressing by reducing viscosity. Thus, cream of tartar plus *yeso* gives calcium tartrate plus acid potassium sulfate.

$$KH(C_4H_4O_6) + CaSO_4 \rightarrow Ca(C_4H_4O_6) + KHSO_4$$

This in turn reacts with some of the cream of tartar as follows:

$$KHSO_4 + KH(C_4H_4O_6) \rightarrow K_2SO_4 + H_2(C_4H_4O_6)$$

to give some free tartaric acid. These changes may be written in a single equation as follows:

$$CaSO_4 + 2KH(C_4H_4O_6) \rightarrow K_2SO_4 + H_2(C_4H_4O_6) + Ca(C_4H_4O_6)$$

Plastering is thus a means of converting the weakly acid salt, potassium tartrate, into an equivalent amount of free tartaric acid. The calcium tartrate formed in the reaction is insoluble and the potassium sulfate remains in the wine. By re-

ducing the pH, plastering renders the wine much less susceptible to spoilage by lactic bacteria and slimy wine bacteria. Not all of the plaster of Paris spread on the crushed grapes reacts with the bitartrate of the must, as $CaSO_4$ is only slightly soluble, and rate of solution is slow. Amerine (1948) states that the addition of tartaric acid to the juice is common practice, and in some cases may entirely replace the use of *yeso*. This is necessary in the making of wines to be shipped to countries that have a low legal limit of sulfate in wines.

Sherry is made from the juice of the free run and of a brief and gentle first pressing.

The free run juice drains from the *lagar* into a butt. The crushed drained grapes are stacked around a vertical pole in the *lagar* and a long, narrow strip of esparto grass matting is wound tightly around the heap of crushed grapes to completely enclose them, each end of the strip being held by wooden pegs forced into the mass of crushed grapes. Pressure, applied by hand-operated screw and plate, is rather brief, so that the first pressing juice will not contain too much tannin. The free run and first pressing are combined and constitute the juice out of which sherry is made.

Juice from a second pressing by a more powerful screw or hydraulic press is used for making dry wine for local consumption. The pomace from the second pressing may be mixed with water, pressed and this diluted juice fermented for distilling material; or some of the wine may be used as a pomace wine by the workmen.

Amerine (1948) states that when treading is omitted hydraulic presses are used for the first and second pressing, followed by continuous or rack and cloth type presses for the third pressing. The juice from the first and second pressing is used for making sherry and that from the third pressing for preparing distilling material or pomace wine.

Flor yeasts naturally present on the grapes carry on the fermentation.

According to de Castella (1926) neither SO_2 nor pure yeast cultures are used. However, Bobadilla (private communication, 1947) states that SO_2 is frequently added to the must to insure a clean fermentation and freedom from spoilage bacteria. Amerine (1948) confirms this statement. Special earthenware funnels or special tubes are inserted in the bung holes of the butts of fermenting must to prevent heavy loss of juice by frothing. Some butts of juice are moved to Jerez, Sanlúcar or Puerto Santa Maria for fermentation; some remain at the crushing house during fermentation. The butts of new wine may remain in the open until the first racking in November and December, although some are placed indoors before fermentation is complete. The musts are not cooled artificially during fermentation.

FIRST CLASSIFICATION

Wines are classified into three groups, largely by taste, before entering the solera.

According to Amerine (1948) at the time of the first racking each butt of new wine is carefully tasted, analysed, and classified into one of three general groups, namely, one, two and three *rayas*, and the butts marked *1, 11,* and *111*. Later, when flor films have formed on those wines on which it can develop, the wines are classified again, this time as *palmas, cortados,* and *rayas*. There are several sub-classes in each of these major groups. This rather complex system of classification will be described only briefly here.

The *palma* wines possess the composition, flavor, bouquet and color desired for producing *fino* and *amontillado* sherries and, therefore, are the most desirable of the new wines. They are pale in color, completely dry, delicate in flavor and

bouquet and resemble a young dry white table wine, although of lower acidity. They should contain 14.5–15.5 per cent alcohol and be free of any suggestion of coarseness of flavor and bacterial spoilage. If the alcohol content of the *palma* wine is below 14.5 per cent, neutral high-proof brandy is added to bring it to 14.5–15.5 per cent at time of first racking.

Next in quality are the *cortado* wines. These are more generous or "bigger" wines than the *palmas* and are of higher alcohol content, often of darker color, but free of coarseness of flavor and bouquet. They are the wines from which *oloroso* sherries are made. If one of these wines is still fermenting in late November or early December, racking may be delayed until mid-winter. They are usually of 16 per cent or higher alcohol content, or if below 16 per cent and distinctly of *cortado* type may be fortified to 16 per cent or above. Bobadilla (1947) and Amerine (1948) state that all *cortado* wines are now fortified to 18 per cent alcohol.

A wine between a *palma* and a *cortado* may be classed as a *palo cortado,* which may develop into a *fino* during aging.

The *raya* wines constitute a group of lower grade. At time of classification they are often not as far advanced as the *palmas* and *cortados,* and it is not certain whether or not they may develop into something better. Thus a good, or *una raya* wine may become a *fino* or an *oloroso,* although it has not progressed far enough for a *fino* at the time of first classification. A *dos rayas* wine is of lower quality and may be coarse in character, but may develop into an *oloroso* in time. A *tres rayas* wine is of still poorer quality, and may eventually have to be used as distilling material. As with the *palmas* and *cortados,* alcohol may be added to the *rayas* that are too low in this constituent.

After racking, the new wines are usually held several months and examined again before going into solera, and some changes may be made in the previous classification, depending on the development of the wine. During this preliminary storage flor film develops on wine in many of the butts. Wines in this preliminary storage stage are known as *añada* wines.

THE SOLERA SYSTEM

Much of the flavor and bouquet of Spanish sherry is due to the solera system of aging wines.

Strictly speaking, the term solera means only the final stage in the Jerez aging system. In most Spanish literature all other stages of the system are called criaderas, and Bobadilla (1947) calls the entire system a "criaderas-soleras" system. De Castella (1909) and Gonzales-Gordon (1935) suggest that solera is derived from the word *suelo,* meaning ground, or floor of the *bodega,* since the butts of the last stage (solera) rest on the floor of the cellar, or on skids a few inches above the floor.

However, members of the Spanish sherry trade generally use the term solera to mean the entire system, including all stages, and we so use it in this paper.

Following is F. de Castella's (1926) excellent description of a solera:

> A solera is a series of butts of sherry in process of maturation or rearing, so arranged as to provide for progressive, fractional blending. It is divided into a varying number of stages; from the final stage is withdrawn the finished wine, whilst young wine is introduced into the earliest stage. Let us suppose for the sake of illustration a solera of 50 butts divided into 5 stages each containing 10 butts is being operated. The butts are of 115 gallons capacity (Imperial gallons, about 130 U. S. gallons), but as they are a little ullaged, their net content would be about 100 Imperial gallons. This solera has been functioning for many years; when first established each stage probably represented a single vintage, but with continual replenishing these have long since lost their original significance.

Stage I contains the oldest wine; from it the finished wine is withdrawn, but in doing so the butts are only partially emptied, not more than one-half being removed in any one year. Withdrawal is usually made twice a year, 25 gallons being removed on each occasion. Butts of stage I are immediately replenished from stage II, which in turn is replenished from stage III and so on. Stage V is replenished with young wine or with wine kept as an *añada* for a year or even longer. The usual age is a few months.

The wine thus moves steadily forward through the different stages until its final withdrawal, when it is a complex blend, none of it being less than 5½ years old, but containing in varying proportion still older wine, including very small quantities of every wine that has gone into the solera since its establishment.

A solera on the above lines would yield only 500 gallons of finished wine each year, from a stock of 5,000 gallons. Interest and loss by evaporation* render it impossible for a solera wine to be reared at a low price. Nor is the above an extreme sample. Soleras differ in the number of their stages. For the rapidly developing *manzanillas* of Sanlúcar three or four stages is the rule. Five or six stages are frequent in *fino* soleras at Jerez, although some consist of eight or nine, turning out as might be expected very expensive wines.

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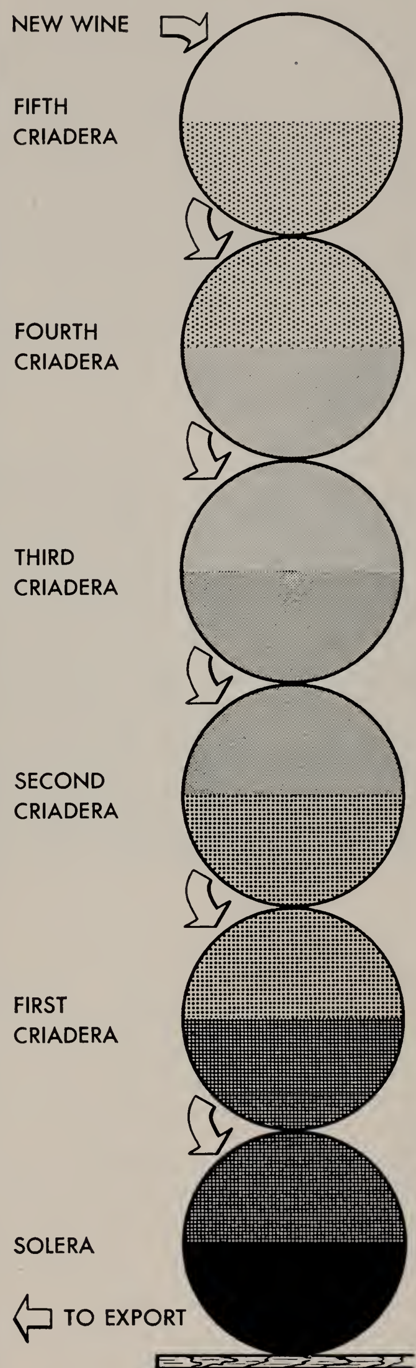
Though it (the solera system) finds its greatest utility in connection with *fino* wines, it is now generally applied to all types. *Oloroso* and *amontillado* soleras, owing to their strength, have no flor on the surface of the wine. With

FIG. 4: SCHEMATIC CHART OF A THEORETICAL SOLERA SYSTEM OPERATING IN 1938



(Courtesy of Pedro Domecq)

* Gonzales (1935) reports that the loss in volume by evaporation is about 4 gallons per year for each 100 gallons of wine in the butts, but that it will vary considerably according to ratio of surface exposed to volume, location in the cellar, temperature and other factors.

these the merit lies in the automatic blending and uniformity of product the system assures. In addition to the above, composite soleras are to be met with, destined for the production of special wines of very high price. One of these might be termed a solera of soleras, the youngest stage being replenished with a blend of finished wines from other soleras; such complex soleras comprise very few stages.

In replenishing one stage from the preceding, the Spanish do not merely add 25 gallons from one butt to another butt in the next stage. A part of each butt in a given stage goes into every butt of the next stage. The amount taken from a butt in stage II, for example, will be divided among all the butts in stage I, in order to ensure uniformity throughout the solera. Each butt of stage III will be divided among all butts of stage II, and so on.

To accomplish the transfer, wine is drawn off by syphon and special pitchers, or directly into pitchers from a small bung hole near the bottom of the butt. It is poured into the butts of the following stage by means of a funnel and a copper tube, with perforations near the bottom, which is inserted into the bung hole. Wine poured through this tube flows out sidewise through the perforations, thus disturbing neither the lees nor the flor film.

The wine is rather freely exposed to the air in the butts, the bung holes being loosely fitted with large corks, according to Gonzales (1935) and de Castella. This is done in the belief that too abundant an air supply results in flatness of flavor rather than in development of the pungent bouquet and flavor of a *fino*.

Marcilla, Alas and Feduchy (1936) give the following analysis of a Spanish *fino* wine of high quality before final fortification: alcohol 16.50 per cent, glycerine .041 grams, aldehydes .0294 grams, volatile esters .051 grams, total acid as tartaric 0.585 grams, volatile acid .022 grams, total sugars .095 grams, total ash 0.584 grams, potassium sulfate 0.478 grams, total extract 2.57 grams per 100 c.c. and total SO_2 58 p.p.m.

They found the composition of five wines of a typical solera to be as follows:

Stage	Alcohol (Volume %)	Glycerine (gms. per 100 c.c.)	Aldehydes (gms. per 100 c.c.)
New Wine	15.70	.76	.0020
Third Criadera	15.80	.64	.0048
Second Criadera	15.45	.63	.0038
First Criadera	15.60	.45	.0189
Solera (oldest)	16.30	.34	.0310

Bobadilla (1943) states that the following conditions should be observed in establishing and operating a *fino* solera.

1. There should be abundant surface of wine exposed to air in each butt, i.e., the head space should be not less than 20 per cent.

2. The temperature should not exceed 25° C. (77° F.) nor be below 15° C. (60° F.), the optimum being about 20° C. (68° F.).

3. The alcohol content should not be above 15.5 per cent nor below 14.5 per cent. Above 15.5 per cent flor film growth may be slow or absent and below 14.5 per cent acetification is apt to occur.

4. The SO_2 content should not exceed 180 p.p.m.; above this level growth of the film is difficult.

5. The tannin content must be very low (not above 0.01 per cent), else the color is apt to be dark and the flavor coarse.

6. Iron content should be low as there are indications that excessive amounts of iron salts interfere with film growth (and may cause clouding).

7. The pH value should be between 2.8 and 3.5. Below pH 2.8 film formation is difficult; above 3.5 there is grave danger of bacterial spoilage. In Spain plastering usually ensures a pH within this range. (Amerine states that addition of tartaric acid will also insure correct pH.)

Fig. 5. Drawing wine from a solera in a Jerez cellar. (Pedro Domecq.)

THE FILM

Flor yeasts usually form a film over wine soon after the completion of fermentation. In a solera wine is drawn off and replaced without disturbing this film.

Normally a thin smooth film or "veil" develops on the new wines within a few days after completion of fermentation. It is composed of cells of the same race of yeast that fermented the must. If the film is slow to develop, transfer is made from a butt of wine covered with vigorous film. Bobadilla (1943) advises such transfer as regular practice.

At first islands of film form. These grow and coalesce to form a smooth, thin continuous film. Within a few weeks it thickens and becomes wrinkled. With abundant air supply young film is nearly white in color. Old film is apt to be gray and with scanty air supply may become light brown.

As the film thickens and becomes wrinkled, portions break away and sink to the bottom of the container, to be replaced by growth of new film. The yeast sediment slowly autolyzes (digests or

liquefies itself), a process that undoubtedly affects the flavor and bouquet of the wine.

Once a flor solera is established the film is allowed to grow relatively undistubed on the wines in all stages of the solera. The butts are seldom emptied; hence the yeast sediment formed of film that has settled to the bottom of the butts is allowed to accumulate. Amerine (1948) states that butts may be emptied and cleaned after several years' sediment has been allowed to collect.

BLENDING AND FINISHING

Spanish wines get their uniformity from the solera system and skillful blending, their clarity from egg whites and Spanish clay.

The usual sherry exported from Jerez is a blend, often a rather complex one. The producers of well-known, established brands of sherry attempt to make wines that are uniform in color, bouquet, flavor and composition regardless of the year of bottling, although they are not always successful. In addition to the exported brands considerable sherry is blended on order, usually to duplicate wines bought in previous years by various importers, particularly in Great Britain (de Castella, 1909).

The *fino* wines are usually sweetened slightly by the addition of a small amount of sweet wine such as *Pedro Ximénèz,* but but in order to retain the full *fino* character, a *fino* wine is usually blended only with other *finos.* For increasing the color of a wine such as an *oloroso, vino de color* may be added. Small amounts are used in a preliminary blend to establish the proportions of the various wines to be used, and this is compared with samples of the wine to be duplicated. Experience and a keen and "educated" sense of taste and smell are necessary qualifications for a successful blender.

Requisite amounts of the various wines to be used in the blends are usually drawn from the last stage of the soleras and blended in a tank of suitable size. However, in periods of heavy demand wine for bottling may be drawn from preceding stages also, which may account for the present occasional deviation from the usual quality of Spanish sherries on the American market. If necessary, the blend is fortified with brandy of very high proof and of smooth, neutral flavor. During aging in the solera, wines increase in alcohol content by more rapid evaporation of water than alcohol, and, according to Bobadilla (1943), *olorosos* usually require no fortification at time of final blending for bottling. As previously stated, they are fortified to 18 per cent alcohol when they are still new wines.

The aged wine is clarified, and filtered if need be. Gonzales-Gordon (1935) states that the best method of clarification consists in beating the required number of fresh egg whites with several liters of the wine and mixing this solution thoroughly with the entire amount of wine to be clarified. He states that from 4 to 20 egg whites per 100 gallons of wine are needed.

After addition of the egg whites, Spanish clay (*tierra de Lebrija,* or "Lebrija clay"), properly prepared by soaking and agitation in wine, is usually added. Gonzales-Gordon (1935) describes its preparation as follows:

> The clay is first soaked in water six to eight hours and the water is discarded. The clay is then placed on a table and worked thoroughly with a roller to reduce it to a paste, and to eliminate sand and gravel. It is then placed in a jar with about two gallons of wine for each kilogram (2¼ pounds) of original clay, dry weight. The wine is added slowly and mixed vigorously. This mixture is then added to a butt of the wine previously treated with the egg whites.

The final blend may also be given a polishing filtration. It is then either bottled in Jerez, or is shipped in butts to New York, London or some other impor-

tant sherry importing port, where it is racked, filtered if necessary, and bottled.

SPOILAGE

SO_2 and higher alcohol content have reduced spoilage in modern Jerez wineries.

Bobadilla (1943) reports that new wines of low acidity and low SO_2 content may become slimy or viscous and that such wines are swarming with bacteria in which very short rods or cocci predominate. He believes that this disease is not due to any one specific microörganism and that low acidity is as important as the spoilage organisms in bringing it on. He states that acidification accompanied by addition of SO_2 will arrest the spoilage without affecting the wine's flavor, and that the viscous condition disappears in a few weeks after a vigorous flor film again develops on the wine. The diseased wine should be cured in this manner before entering the solera.

If the alcohol content is too low acetification may occur. Bobadilla says the remedy and preventive is simple; fortify to 15–15.5 per cent alcohol. He also recommends addition of SO_2.

There is some danger of spoilage due to lactic bacteria. Addition of SO_2 is the approved cure and preventive measure.

INVESTIGATIONS

Over a period of about twelve years (1936–1948) we have studied the Spanish methods of sherry making already described, and the properties of flor yeasts, to determine how they might be adopted for use in California wineries. In addition to many experiments in the laboratories of the Food Technology Division, University of California, we have had the coöperation of fifteen California wineries in carrying out experiments on a large scale and under actual winery conditions.

Our results indicate that flor yeasts, and a modified solera system, can be successfully used in California for the production of flor wines. Details of our investigations appear below.

PROPERTIES OF FLOR YEASTS

Nine strains of flor yeast from Jerez and six from Arbois, France, were used in our experiments.

Fifty pure yeast cultures were isolated from mixed cultures, and 15 of these were selected as differing sufficiently to constitute distinct species and strains.

The French flor yeasts were included, because in the Arbois district, near Dijon, they are used to produce a famous sherry-like unfortified white wine known as *vin jaune* (yellow wine) of Arbois. These yeasts form films that very closely resemble those of Jerez flor yeasts, and they produce changes in the wine very similar to those induced by Jerez yeasts. One of the most famous of the Arbois wines is Château Chalon.

For convenience we shall refer to the Spanish film yeasts as "Jerez yeasts," and to the French film yeasts as "Chalon yeasts." They are also referred to by laboratory numbers as shown in table 1.

Dr. H. Ferré, director of the enological station in Beaune, supplied mixed cultures of the Arbois film yeasts, and one of us (W.V.C) obtained additional samples when in Beaune in 1939. Some Jerez yeasts, originating from several sources in Jerez de la Frontera, were obtained from Dr. Hugo Schanderl of the wine research laboratory of Geisenheim, Germany, from Arnuf Franz, a former student of Dr. Schanderl, and from V. N. Chopra of India. Others were taken from imported Spanish sherry.

Pure cultures were made by plating directly from the mixed flor yeasts as re-

Table 1: CHARACTERISTICS OF FILM (FLOR) YEASTS FROM JEREZ AND CHALON WINES.

Yeast Number	Source	Microscopical Appearance of Cells	Spores	Fermentation in Grape Must	Classification
1	Arbois	Oval to sausage-shaped	Form readily 2–3 per cell	Very slight	Pichia
8	Jerez	Long to sausage-shaped	Form readily 2–3 per cell Hat-shaped	Very slight	Pichia
9	Arbois	Oval to sausage-shaped	Form readily 2–3 per cell Hat-shaped	Very slight	Pichia
10	Arbois	Ellipsoidal	Spherical 2–4 per cell	Vigorous	Saccharomyces cerevisiae, ellipsoideus
2	Jerez	Ellipsoidal	Spherical 2 per cell	Vigorous	Saccharomyces. Closely resemble S. cerevisiae ellipsoideus
3	Jerez	Ellipsoidal	Spherical 2 per cell	Vigorous	As above
4	Jerez	Oval	Spherical 2 per cell	Vigorous	As above
11	Arbois	Ellipsoidal	Spherical 2 per cell	Vigorous	As above
12	Arbois	Ellipsoidal	Spherical 2 per cell	Vigorous	As above
13	Arbois	Ellipsoidal	Spherical 2 per cell	Vigorous	As above
H-2	Jerez	Oval to spherical	Saturn-shaped 2 per cell	Slight	Hansenula
5	Jerez	Oval to ellipsoidal	None formed	Vigorous	Torulopsis species
6	Jerez	Oval to ellipsoidal	None formed	Vigorous	Torulopsis species
7	Jerez	Oval to ellipsoidal	None formed	Vigorous	Torulopsis species
H-1	Jerez	Oval to ellipsoidal	None formed	Vigorous	Torulopsis species

ceived, and also by transferring the mixed cultures to sterile grape juice, fermenting, and plating from the films that formed after fermentation had ceased.

CLASSIFICATION

Typical flor yeasts are Saccharomyces whose distinguishing characteristic is their ability to form films on wine.

The yeasts were classified and characterized (table 1) on the basis of microscopical appearance, spore formation on standard and on special media, and fermentation characteristics in solutions of various sugars.

Yeast 10 formed very little film; all others formed films rapidly on wines of suitable alcohol content. Yeasts 1, 8, 9, and H-2 produced very little fermentation. All others were fermentative.

Yeasts 2, 3, 4, 11, 12, and 13 were similar in respect to general morphology, spore formation, and fermentation behavior, and were designated as Group C. All formed spores, although relatively few cells developed spores, and several were very slow to do so.

Yeasts 5, 6, 7, and H-1 were similar to those of Group C, except that in two months they failed to form spores on any of the many spore media tested. They have been placed, at least temporarily, in a non-sporulating genus, *Torulopsis*, and were designated Group E. It is possible that these yeasts might eventually be induced to sporulate. Except for film formation and lack of sporulation they very closely resembled *Saccharomyces cerevisiae*, var. *ellipsoideus*.

Bobadilla (1943) speaks of the flor yeasts of Jerez wines studied by him as true wine yeasts, thus implying that they formed spores, and Marcilla, Alas and Feduchy (1936) state that the flor yeasts studied by them formed spores. From these observations it might appear that sporulating flor yeasts are more common than the non-sporulating.

MICROSCOPICAL APPEARANCE

Jerez yeast cells are larger than Chalon, while both appear smaller and more granular in the film than in the fermentative stage.

Our fermentative Jerez and Chalon yeasts, when in full fermentation, resembled typical true wine yeasts, *Saccharomyces cerevisiae, ellipsoideus,* in microscopical appearance. They ranged in form from short ellipsoidal or oval to rather long ellipsoidal. The size range from about $3.1 \times 3.9\mu$ to about $7.7 \times 10\mu$. The general impression obtained by examining mounts of Jerez and Chalon yeasts from fermenting sweet beer wort medium is that the Jerez yeasts were somewhat larger in size than the Chalon yeasts.

Cells from the film stage were smaller and more granular than those from fermenting must or beer wort, and were inclined to adhere together in clumps. Some of the film cells possessed two buds each. There was also greater variation in size, some cells being very large and almost spherical, others being exceptionally small. Figure 6 illustrates the microscopical appearance of cells from the fermentation and film stages.

CHALON AND JEREZ COMPARED

Chalon yeast imparts more flor characteristics to wine than Jerez yeast, but both are entirely satisfactory.

In a laboratory comparison test in January, 1938, about 20 gallons of one-year-old Palomino wine was placed in each of two 25-gallon barrels. One was inoculated with Jerez yeast 5, the other with Chalon yeast 12 film. They were stored in a room where the night temperature often reached 80° F. because of exposed steam pipes, and the day temperature ranged from about 65 to 75° F. Film growth and ac-

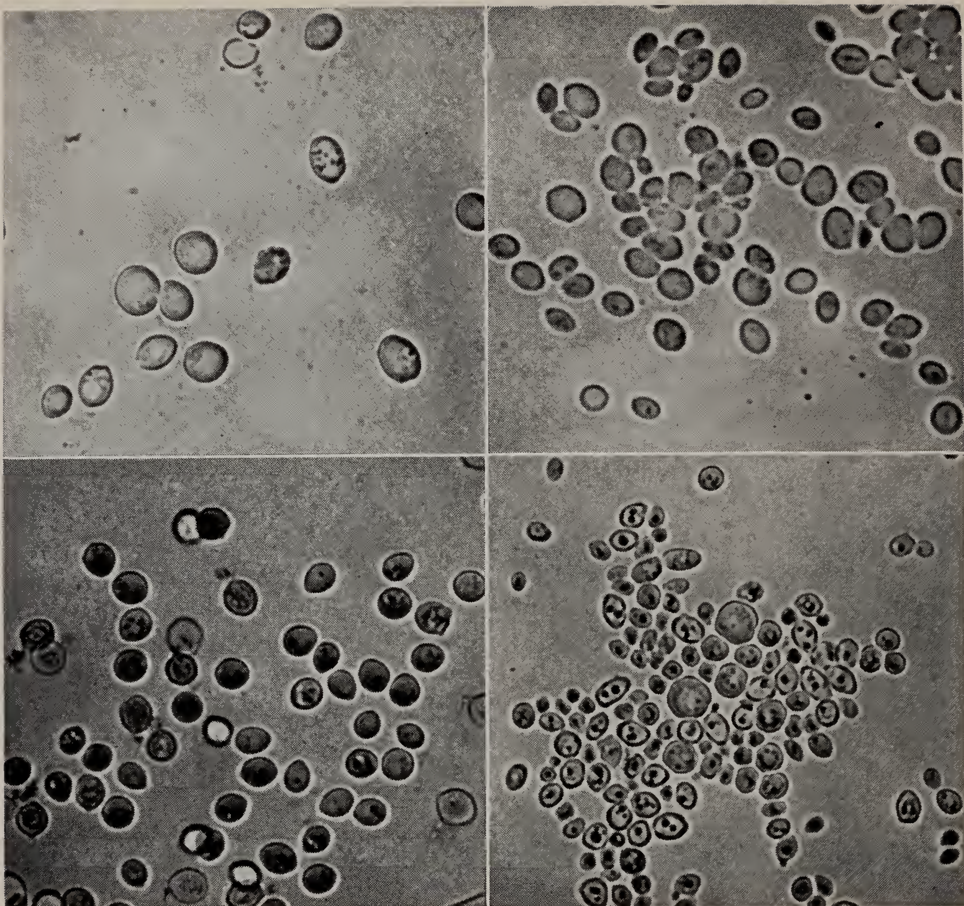


Fig. 6. Flor yeasts under microscope. Top, Jerez yeast No. 5, fermentation stage left, film stage right; Bottom, Chalon yeast No. 12, fermentation stage left, film stage right.

tivity were more vigorous than in wines under film in cooler laboratories.

Both wines developed pronounced flor wine bouquet and flavor in 12 months, and small portions were fortified in the laboratory after about 24 months under film. Other portions of each were bottled without fortification. Both were very pale in color and of pronounced flor wine bouquet and flavor. The Chalon wine was slightly more pungent in bouquet than the Jerez. Both resembled rather closely our samples of Arbois flor wines from France. As in most of our experiments, the Chalon yeast appeared to be somewhat superior to the Jerez yeast, although the difference was not marked, and both were entirely satisfactory.

ALCOHOL FORMATION

In fermentation all experimental yeasts produced, at about equal rates, more than 15.5 per cent alcohol, when the must contained sufficient sugar.

Several experiments were made to ascertain the alcohol-forming power of the Jerez and Chalon yeasts in both straight and siruped fermentations. Alcohol contents of the fermented samples are given in table 2.

In experiments reported by Hohl and Cruess (1939) fresh grape must from Semillon grapes was reinforced with grape concentrate to 30° Balling, and

sterilized in 600 c.c. portions in quart bottles plugged with cotton. Bottles of the sterile juice were inoculated in duplicate with pure cultures of the fifteen yeasts and with Champagne Ay yeast and allowed to ferment at room temperature, approximately 65–70° F., until fermentation ceased.

Siruped fermentations were also conducted. Sterile 500 c.c. portions of fresh grape must were inoculated in duplicate with most of the yeasts. When fermentation had reduced the Balling degree to nearly 0 as judged by loss in weight of the bottles and contents, we added sufficient sterile grape concentrate to increase the Balling about 10 degrees. Fermentation was then allowed to continue until there was no further change in Balling degree.

All of the true flor yeasts gave 2 per cent or more alcohol than did the Champagne Ay yeast. Such a difference might not be maintained under other conditions, however, since in other experiments the Champagne Ay yeast has formed over 16 per cent alcohol. The Jerez yeasts formed slightly more alcohol, on the average, than did the Chalon yeasts, but several of the Chalon yeasts formed more alcohol than did Jerez Number 3. In most cases the alcohol formed in siruped fermentations was more than 1 per cent above the corresponding values by straight fermentation. Yeasts 4 and 5 attained 19.1 and 19 per cent alcohol respectively by siruped fermentation.

These experiments indicate that it is not difficult to attain 15.5 per cent alcohol content in wines intended for aging by the flor procedure, if the must contains sufficient sugar.

Both Jerez and Chalon fermentative yeasts had normal wine yeast fermentation rates, differing little from those of Champagne Ay and Burgundy yeasts in the University's yeast collection. Therefore, tables and graphs of fermentation data have been omitted from this publication.

ALCOHOL TOLERANCE OF FILM

Film growth may occur when alcohol content is as high as 17 per cent, but the lower the alcohol, the more vigorous the film.

In a laboratory experiment 600 c.c. portions of white wine, free of SO_2, were brought by blending to various alcohol contents ranging from 12 to 17 per cent. The bottles were crown capped and the wines pasteurized. The caps were replaced with sterile cotton plugs, and the wines were inoculated with the film stage of each yeast in duplicate. The cultures were stored at 65–70° F. and as soon as definite film formation appeared analyses were made of alcohol content.

Table 2: ALCOHOL FORMATION BY FLOR YEASTS AND CHAMPAGNE AY YEAST.

(Expressed as per cent by volume)

Yeast	Alcohol (Straight fermentation)	Alcohol (Siruped fermentation)
1. Arbois. Pichia	0	0
2. Jerez. Saccharomyces	17.5	18.4
3. Jerez. Saccharomyces	16.0	17.6
4. Jerez. Saccharomyces	18.0	19.1
5. Jerez. Torulopsis	17.5	19.0
6. Jerez. Torulopsis	18.0	18.8
7. Jerez. Torulopsis	17.6	18.0
8. Jerez. Pichia	0	0
9. Arbois. Pichia	0	0
10. Arbois. Sacch.	17.7	18.8
11. Arbois. Sacch.	16.2	18.2
12. Arbois. Sacch.	15.9	18.3
13. Arbois. Sacch.	17.4	18.4
H-1 Jerez. Sacch.	17.4	no data
H-2 Jerez. Hansenula	0.3	no data
Champagne Ay	15.6	no data

Table 3 summarizes the observations made. Nine of the yeasts formed films at or above 16 per cent alcohol and two at 16.4 per cent, the highest level at which growth was observed in these tests.

In another laboratory experiment it was found that the film stage could be acclimated to grow feebly at 17 per cent

alcohol by volume, but not on wines of higher alcohol content.

However, it was observed in this and other experiments that growth is less vigorous and the film is considerably thinner at 16.3–17.0 per cent alcohol than at 15–15.5 per cent. The heavier the film the more rapid is the development of the wine, and the lower the alcohol content, within reasonable limits, the more vigorous is the film.

The Jerez yeasts generally showed slightly higher average alcohol tolerance than the Chalon yeasts, and developed films somewhat more rapidly.

Table 3: LABORATORY EXPERIMENTS ON ALCOHOL TOLERANCE OF FILM STAGE.

Yeast	Original alcohol (Volume %)	Alcohol when film appeared (Volume %)	Days at room temperature to form films
1	14.5	12.2	10
2	17	16.0	16
3	17	16.4	10
4	17	16.3	10
5	17	16.1	10
6	17	16.2	10
7	17	16.2	10
8	14.5	13.7	16
9	13	11.2	9
10	15	14.6	10
11	17	16.0	16
12	17	16.2	16
13	17	15.4	16
H-1	17	16.0	16

EFFECT OF TEMPERATURE

Flor yeasts will complete fermentation at temperatures as high as 89.6° F., but will not form film readily above 80°.

Duplicate 100 c.c. portions of sterile must of 26° Balling were inoculated with each yeast for each temperature used, and incubated at 68–71.6°, 80.6–86°, 89.6°, and 98.6° F.

The *Pichia* and *Hansenula* yeasts, 1, 8, 9 and H-2, grew well at all four temperatures but formed no alcohol. The other yeasts fermented satisfactorily and to completion or nearly so at 68–71.6°, 80.6–86°, and 89.6° F., although Jerez yeast number 6 stuck with some unfermented sugar at 89.6° F. At 98.6° F. none of the yeasts completed its fermentation. At that temperature number 2 stuck at 8° Balling, 3 at 7.3° Balling, 4 at 4.3° Balling, 5 at 6.3° Balling, 6 at 15° Balling, 7 at 5.4° Balling, 10 at 5.4° Balling, 11 at 7.6° Balling, 12 at 8.1° Balling, 13 at 7.4° Balling, and H-1 at 7° Balling.

In respect to effect of temperature on completeness of fermentation the fermenting types of our Jerez and Chalon cultures, with the exception of number 6, resemble standard wine yeasts, such as Champagne Ay, Burgundy and Tokay, of the University's collection. Number 6 was somewhat more sensitive to high temperature than were the other cultures.

At room temperature (68–70° F.) all of the cultures formed films readily. At 80.6–86° F. film formation was very scanty except by the *Pichias* and H-2 (*Hansenula saturnus*). At 89.6° F. none of the alcohol-forming yeasts formed films. In other experiments Jerez 5 and Chalon 12 yeasts failed to form films at 85° F. on 3000 c.c. lots of wine of approximately 15.5 per cent alcohol content.

Somewhat high temperatures, while still suitable for fermentation, are too warm for film formation. Our data confirm the observations of Bobadilla (1943) Gonzales-Gordon (1935) and others on temperature requirements for film formation, and further bear out our experience in the conduct of flor sherry experiments in two California wineries. In these experiments, when summer temperatures rose above the maximum for film growth, the films on the wines broke and settled to the bottom of the butts. Films reappeared with cooler weather in the fall. This phenomenon is mentioned frequently by several writers on Spanish sherry, and

is evidently well known in Jerez de la Frontera.

The four film formers *Pichia* and *Hansenula* were much more tolerant to warm temperatures, but because of their low alcohol tolerance we believe they are of little importance in flor wine production.

TOLERANCE TO SO_2

Although flor yeasts will tolerate up to 300 p.p.m. SO_2, we recommend concentrations of 100–125 p.p.m. as sufficient to inhibit lactic bacteria.

In the fermentation of grape juice for flor wine production it is essential to use SO_2 in order to inhibit the growth of undesirable yeasts. During the aging of wine under flor yeast film it is advisable to maintain a sufficiently high SO_2 concentration to prevent the growth of anaerobic and facultative aerobic bacteria, particularly those of the *Lactobacillus* group, such as the so-called *tourne* bacillus. We therefore undertook to learn the approximate tolerance of the flor yeast for SO_2 in fermentation and film formation.

Dilute sodium bisulfite solution was added to sterile portions of grape juice, to give SO_2 concentrations ranging from 100 to 1000 p.p.m. The juices were heavily inoculated with pure cultures of the alcohol-forming strains of Jerez and Chalon yeasts, and held at room temperature. All grew readily and developed vigorous fermentation in less than a week in juices initially containing 300 p.p.m. or less of SO_2. Several fermented juices that had received 500 p.p.m. of SO_2. In other words, the flor yeasts used in this experiment exhibited normal *Saccharomyces cerevisiae* var. *ellipsoideus* yeast tolerance to SO_2, although Marcilla (1946) reports lower SO_2 tolerance for his cultures.

The film stage of these yeasts was also found to be moderately tolerant of SO_2. In a typical experiment, dry white wine of 15.5 per cent alcohol was brought to total SO_2 contents of 100, 150, 175, 200, 225, 250, 300, 325, and 350 p.p.m. by the addition of 10 per cent sodium bisulfite solution. Duplicate samples at each SO_2 concentration were inoculated with Jerez yeast 5 and other duplicate samples with Chalon yeast 12. The samples were stored at room temperature. Within three weeks heavy, wrinkled films had formed on all of the wines initially containing 250 p.p.m. or less of SO_2, and within four weeks films had appeared on the wines to which 300 and 350 p.p.m. had been added.

Our data confirm the statements of Bobadilla (private communication, 1947) that the flor film will grow readily under cellar conditions on wine in 130-gallon butts at 180 p.p.m. of total SO_2 if the free SO_2 is not in excess of 5 per cent of the total. He recommends that SO_2 be used to inhibit spoilage bacteria. On the other hand, Williams (1943) of Australia opposes its use, because he believes it lessens the intensity of the bouquet and flavor developed by the flor film.

We have found that wines containing considerable total SO_2 with initial SO_2 concentrations up to 300 p.p.m. developed into *fino* type sherries of good quality under flor film. However, we do not recommend high SO_2 concentration; at no time need it be above 150 p.p.m. If it is maintained at 100–125 p.p.m., lactic bacteria will be held in check.

ALDEHYDE FORMATION

Aldehyde increases during aging of flor wines, and contributes to their flavor and bouquet.

In an experiment conducted in 1938, wine of an initial aldehyde content of 11 p.p.m. was inoculated with the film stage of each of the fermentative yeasts. In three months at room temperature the aldehyde content had increased to a range of 100–135 p.p.m. In a similar experiment conducted in 1945 with the

same yeasts the total aldehyde content after six months incubation at room temperature ranged from 41.5 p.p.m. for Jerez yeast H-1 to 153.0 p.p.m. for Jerez yeast number 5.

Joslyn and Amerine (1941) and other writers on Spanish sherries believe that much of the flavor and bouquet of flor sherries is due to the presence of aldehyde and its reaction products. This appears to be a logical deduction, since aldehyde increases during the flor aging process, since the flavor is in some degree similar to that induced by added aldehyde, and since secondary products, such as acetals, etc., are formed. From recent data of Mackinney and others on the darkening of fruit products the aldehyde of sherry is probably involved in the darkening of sherry during aging.

ESTER FORMATION

Volatile ester content is not high, nor are any specific esters recognizable by odor in our flor wines.

Ester formation was not followed systematically, although in an experiment with 3-gallon lots of wine under film there was evidence of formation of moderate amounts of total esters. The final volatile ester content ranged from 18.5 to 28.2 p.p.m. Volatile ester content is not extremely high, else it would be perceptible to the sense of smell. We were not able to recognize any specific esters such as ethyl acetate in our flor wines. In this, flor sherry differs from dry table wines.

EFFECT ON VOLATILE ACIDITY

Flor yeasts reduce volatile acidity of wines, and often can thus prevent or correct acetification, particularly when alcohol content is high enough to inhibit growth of vinegar bacteria.

It is well recognized in Jerez de la Frontera that flor yeasts reduce the volatile acidity, i.e., acetic acid, by oxidation. Schanderl (1936), Marcilla (1946) and Bobadilla (1943) state that one of the chief characteristics of flor yeast is its ability to destroy acetic acid and thus correct acetified wines that have not become too high in acetic acid to permit the yeast to grow. Bobadilla reports that a wine with 0.277 grams volatile acidity per 100 c.c. was inoculated with flor yeast, and in 23 days a film had formed. In 163 days the volatile acidity had been reduced to 0.160 grams per 100 c.c.

Pasteur, in his studies on the wines of Arbois, France, nearly ninety years ago, observed that the film yeast of these wines "waged a battle" with the vinegar bacteria for supremacy and that when the yeast won it decreased the volatile acidity to give a potable wine, but that when the bacteria won, the wine turned to vinegar.

In both laboratory and winery experiments our observations confirmed the findings of Pasteur, Marcilla, Schanderl, and Bobadilla on the ability of flor yeasts to reduce the volatile acidity of wines high in this constituent. For details of the laboratory experiments see Cruess and Podgorny (1937).

Table 4

Original volatile acidity (gms./100 c.c.)	Volatile Acidity after Six Weeks under Film								
	Yeast 2	Yeast 3	Yeast 4	Yeast 5	Yeast 7	Yeast 11	Yeast 13	Yeast H-1	Yeast H-2
0.191	0.03	0.009	0.015	0.012	0.030	0.012	0.194*	0.012	0.012

* No growth.

Fig. 7. Picking grapes near Jerez de la Frontera. (Pedro Domecq.)

Table 4 summarizes some of our data. In several experiments 100 p.p.m. of SO_2 was added to arrest acetification, but halted it only temporarily.

These experiments indicate that addition of 100 p.p.m. of SO_2 will not always arrest acetification, and that acetification can proceed readily at 14.7 per cent alcohol under winery conditions. This is 0.20 per cent higher alcohol content than the minimum recommended by Bobadilla (1943) and Gonzales-Gordon (1935). In several other experiments in various wineries acetification was successfully arrested in wines by adding sherry material to bring the alcohol content to 15.5 per cent or more. We therefore recommend that wines under film be brought

to 15.5 per cent alcohol or more to prevent acetification.

EFFECT ON FIXED ACIDITY

Fixed acidity is also reduced by flor film; the larger the lot of wine, the slower the rate of destruction.

Three-gallon portions of one-year-old white wine of 15.5 per cent alcohol were inoculated with the film stage of ten fermentative strains of Jerez and Chalon yeasts. Total acidity was determined by titration at monthly intervals during six months incubation at room temperature.

At three months the initial total acidity of .435 grams per 100 c.c. had been reduced to an average of .385, with a range of .435 to .318 grams per 100 c.c. At six months the average was .312 and the range was .278 to .338 grams per 100 c.c. Volatile acidity was reduced from .054 to .036 grams per 100 c.c.; fixed acidity from .368 to .340 grams per 100 c.c.

Volume and ratio of volume to depth affect the rate of destruction of total acidity. In small lots of wine, 300 to 700 c.c., the destruction of total acidity was very rapid; in several instances initial total acidities of .55 to .60 grams per c.c. were reduced in six months at room temperature to approximately 0.20 grams per 100 c.c., and in one case to less than 0.10 grams per 100 c.c.

To 700 c.c. portions of wine of 15.5 per cent alcohol in quart bottles was added tartaric acid to give total acidities of .54, .75, 1.00, 1.25 and 1.50 grams per 100 c.c. The corresponding pH values were 3.75, 3.25, 3.1, 3.0 and 2.8. The wines were pasteurized, cooled, and inoculated with the film stage of Jerez yeast number 5. Heavy films formed in less than 7 days at acidities of .54 to 1.0 inclusive and in about 14–15 days at 1.25 and 1.50 grams per 100 c.c. In 27 days at room temperature the total acidities had become .44, .62, .88, 1.15 and 1.36 grams per 100 c.c. Similar results were obtained when citric acid and lactic acid were added instead of tartaric acid.

In other words flor yeast can develop at very high total acidity, 1.50 grams per 100 c.c. or higher, and at low pH value, 2.8 or lower and can destroy fixed acid at these values.

Table 5 summarizes data on decrease in total acidity of wines held under film in winery experiments.

CHANGES IN ALCOHOL CONTENT

Although flor yeasts destroy some alcohol, wine under film in lots of 45 gallons or more shows an increase in alcohol content, because in dry climates water evaporates from wood pores more readily than alcohol.

In laboratory experiments with wine in lots of 300 c.c. to 12,000 c.c. the alcohol decreased during storage of the wine under flor yeast films. Thus, in an experiment with ten strains of flor yeasts on 12,000 c.c. (3-gallon) lots of wine of an

Table 5

Winery	Months under Film	Original Total Acidity (gms./100 c.c.)	Final Total Acidity (gms./100 c.c.)
Inglenook	18	0.60	0.38
Italian Swiss Colony	14	0.43	0.37
Solano	23	0.48	0.26

Table 6

Winery	Months under Film	Original Alcohol Content (Volume Per cent)	Final Alcohol Content (Volume Per cent)
Italian Swiss Colony	11	15.80	16.3
Novitiate	20	14.80	15.45
Cresta Blanca	22	14.22	14.70
Cribari	13	15.50	15.90

initial alcohol content of 15.5 per cent, the average alcohol content decreased to 14.7 per cent in three months at room temperature and to 14.2 per cent in five months. In smaller volumes of wine the rate of decrease was even more rapid, and was considerably in excess of that in non-inoculated wine stored under the same conditions.

De Castella (1926), Marcilla (1946), Bobadilla (1943), Williams (1943) and others state that in Spain and Australia it is a well-substantiated fact that the alcohol content of wines in the solera gradually increases under dry cellar conditions because alcohol penetrates through the wood more slowly than water. Our winery experiments confirmed the Spanish experience, as table 6 shows.

FILM AND RESIDUAL SUGAR

Flor yeasts can destroy residual or added sugars, both invert and sucrose.

To find out whether small amounts of unfermented sugar in new wine are attacked by the flor yeast film, we added 1 gram of sucrose per 100 c.c. to wine of 15.5 per cent alcohol. The wine was then pasteurized and inoculated with Jerez yeast 5 film. At time of inoculation analysis showed .67 grams of sucrose and .57 grams of invert sugar per 100 c.c., a total of 1.24 grams per 100 c.c. The wine had contained some invert sugar before we added sucrose.

Twenty-one days after inoculation the sucrose content was negligible, only .01 grams per 100 c.c., and the invert was .24 grams per 100 c.c. At 27 days the sucrose was 0 and the invert .23 grams per 100 c.c.

In an experiment with ten strains of flor yeasts similar rates of reduction of added dextrose in wine of 15.5 per cent alcohol were observed.

FILM GROWTH FACTORS

Ammonium phosphate greatly stimulates film growth. Other added nutrients are less effective.

On some wines growth of the flor yeast film is less abundant than on others. It was thought that there might be some correlation between the food supply and film production. In the production of wines in France from musts low in yeast nutrients it is reported by French authors that ammonium phosphate is sometimes added to promote vigorous yeast growth and fermentation. In France, California, and in other wine-making regions it is customary to add a small amount of ammonium phosphate or urea as yeast food to wines in which fermentation has stuck because of high temperature during fermentation.

In one experiment we added various amounts of $(NH_4)_2HPO_4$ (ammonium acid phosphate) to wine of 15.0 per cent alcohol and 0.142 grams of volatile acid per 100 c.c. Approximately 700 c.c. portions of wine in quart bottles plugged with cotton were used. The wines were inoculated with Jerez yeast number 4 and

incubated at room temperature. Reduction in volatile acidity by the film was used as the criterion of its activity. Fifteen days after inoculation the volatile acidity of each wine was determined and observations made on vigor of film growth with the results shown in the following table.

$(NH_4)_2HPO_4$ gms./100 c.c.	Volatile acidity gms./100 c.c.	Film Growth
0	0.127	Thin
0.10	0.115	Thin, but heavier than check
0.25	.082	Moderately heavy
0.50	.030	Very heavy

In another experiment Chalon yeast number 13 was used, because it develops slowly as a film. The wine contained 15 per cent alcohol and 0.067 grams of volatile acidity. At 15 days the observations given in the following tabulation were made.

$(NH_4)_2HPO_4$ gms./100 c.c.	Volatile Acidity gms./100 c.c.	Film Growth
0	.067	None
0.10	.060	A few islands
0.25	.055	Thin, continuous
0.50	.018	Moderately heavy

In an experiment reported by V. Frasinetti (undergraduate research report, 1942) the addition of 0.30 grams of $(NH_4)_2$ HPO_4 per 100 c.c. markedly increased film production by Jerez yeast 5.

In other experiments by Frasinetti it was found that yeast autolysate materially stimulated film growth but was less effective than $(NH_4)_2$ HPO_4. Asparagine had a noticeable effect but much less than the phosphate. Grape concentrate increased growth somewhat and dextrose had very little effect. The following vitamins and compounds were added in various amounts to portions of the wine, either singly or in various combinations: thiamin (B_1), pantothenic acid, pyridoxin, riboflavin (B_2), inositol, ascorbic acid (C), nicotinic acid as the amide, and biotin. Of these ascorbic acid (vitamin C) and biotin, particularly the latter, had the more pronounced positive effects on growth. Thiamin (B_1) and riboflavin (B_2) showed little effect.

The positive effect of the yeast autolysate is of particular interest because during the storage of wine under flor film the latter frequently breaks and sinks to the bottom of the container, where it slowly undergoes autolysis. It is possible that the substances so released promote formation of additional film.

FILM SEDIMENT AND FLAVOR

Breaking and settling of portions of film produce a yeast sediment which may contribute to the wine's flavor.

The yeast autolysate formed from settled film not only aids in the formation of new film, but may also make a definite contribution to the flavor of wine, particularly to its after-taste. Prolonged contact with this sediment is made possible by the solera system.

In one experiment we added to unfortified wine previously held under film about two years the film yeast sediment from several times its volume of other flor wine. The wine was then stored in the laboratory about one year in a full, closed jug. The effect on flavor was very pronounced. After fortification and aging in a closed container, the wine possessed much of the characteristic flor sherry after-taste. Another laboratory test in which yeast sediment from flor wine was added to fortified flor sherry gave a similar result. We believe that this phenomenon is a very important factor in the development of the flavor of flor sherries under cellar conditions, although further research on this point is needed.

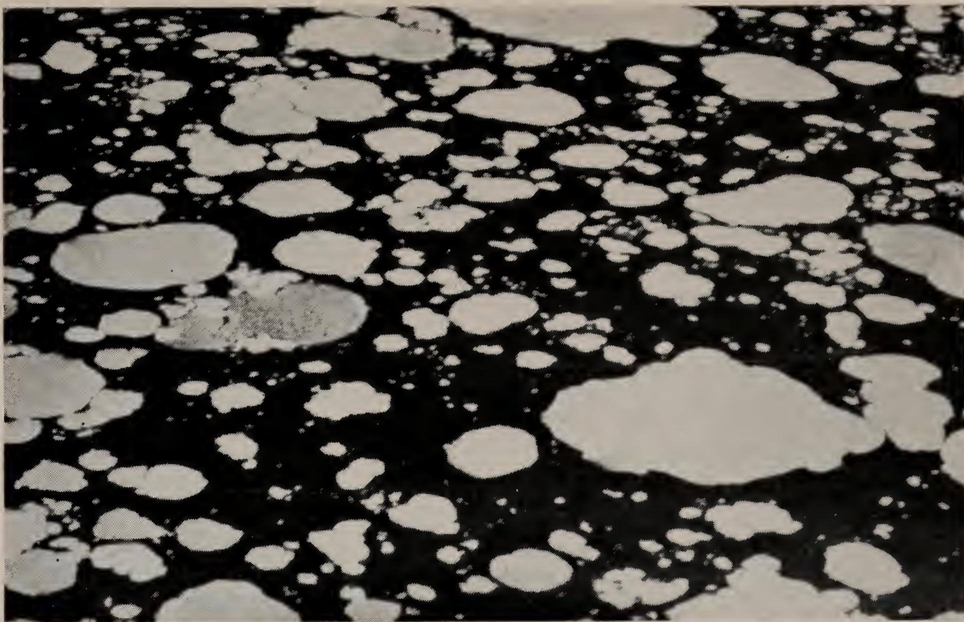


Fig. 8. Islands of spreading flor film on the surface of wine soon after inoculation. (L. Martini, Jr.)

Fig. 9. Later, the active film completely covers the wine's surface in this 10,000-gallon tank. (L. Martini, Jr.)

ROLE OF pH

Wines having a pH range of 3.1 to 3.5 develop vigorous film and are apt to attain the best flor characteristics.

Baker (1945) states that at pH values below 3.0 flor yeast films are thin, dry and slow in forming, and that if the pH is too high, e.g., 3.7 or 3.8, there is apt to be little development of flor sherry bouquet and flavor. He recommends a range of pH 3.1 to 3.3 for maximum development of flor character. Williams (1943) quoting Fornachon (both of Austrialia) states that the lactic spoilage bacteria of wine do not grow in wine at pH values below 3.5. Bobadilla (1943) recommends that the pH of the wine for the flor process be 2.8 to 3.5.

In our investigations white wine of 15.5 per cent alcohol was brought to pH values of 3.95, 3.60, 3.36, 3.20, 3.00, 2.85, and 2.65 by addition of sodium hydroxide for the higher and citric acid for the lower values. Portions of 700 c.c. each in duplicate were inoculated with Jerez yeast 5 and incubated at room temperature.

Two weeks after inoculation film growth was vigorous at pH 3.95–3.0 inclusive, thin at 2.85, and absent at 2.65. However, film growth with destruction of volatile acidity occurred even at pH 2.65 in 26–47 days (table 7).

From pH values 3.95 to 3.0 inclusive there appeared to be little difference in the rates at which the film destroyed volatile acidity. However, at pH 2.65, 2.85 and 3.0 the wine is too acid in taste for consumption.

OXIDATION AND REDUCTION

Oxidation of alcohol and organic compounds occurs near the surface of wines under film, but the bulk of the wine is in a reduced condition.

Oxidation of alcohol, organic acids and probably of other organic compounds occurs in the film, i.e., conditions are strongly oxidative. In the depths of the wine below the film, however, a reducing condition exists, as shown by the bleaching of white wine from amber to a very pale color. In several experiments in the laboratory and in wineries 3000 c.c.—lots and butts of wine with film became pale in color, whereas other lots of the same wines without film became dark in color and oxidized in flavor. Dr. M. A. Joslyn measured the oxidation-reduction potential in the wine before and after film formation and found that the wine under the film was in a reduced condition. This situation is an important factor in the maturation of flor wines.

COMPOSITION OF SPANISH AND CALIFORNIA SHERRIES

Spanish sherries are higher than California sherries in ash and total sulfates, and lower in titratable alkalinity of ash, because of plastering with $CaSO_4$. Otherwise the wines are similar in composition.

As indicated by Joslyn and Amerine (1941), by unpublished analyses of Peter Valaer (1944, 1945), and a few analyses made by us of Spanish and California sherries, similar classes (e.g., dry and medium sweet) are similar in composition, except that most of the Spanish sherries from the American market were higher in total sulfates and total ash but lower in titratable alkalinity of the ash than California sherries, because of plastering of the juices used in making sherries in Spain for export to the U.S.A. For example, Valaer's average values for a group of dry Spanish sherries were: total acid .454 gms./100 c.c., alcohol 19.88 volume per cent, total solids 3.43 gms./100 c.c., ash 0.421 gms./100 c.c. and alkalinity of water-soluble ash 5.7 c.c. of N/10 H_2SO_4 per 100 c.c. For a group of dry California sherries the values were alcohol 20.10 per cent by volume, total acid

.416 gms./100 c.c., total solids 3.80, total ash .295 gms./100 c.c. and alkalinity of water-soluble ash 14.1 c.c. N/10 H_2SO_4 per 100 c.c. Since the present paper is not particularly concerned with comparative composition of sherries and since the number of our analyses was small, actual data are not presented here.

OBSERVATIONS ON PLASTERING

Wines from plastered musts have a lower pH, lighter color, and more flor flavor and bouquet. We therefore recommend use of $CaSO_4$.

Because of the lower pH of wines made from plastered musts there is less danger of spoilage by lactic bacteria. In our experiments it was observed that the wines made from plastered musts cleared more promptly after fermentation was completed and were lighter in color as well as more tart in flavor. The plastered wines also developed more of the flor sherry flavor and bouquet.

Baker (1945) found that the addition of 4 pounds of plaster of Paris per 100 gallons (about 4.8 grams per liter) reduced the pH of Palomino must from 3.88 to 3.41, and of Albillo juice from pH 3.65 to pH 3.27.

In one of our experiments, various amounts of gypsum were added to one-year-old wine, and in another, to fresh must of Thompson seedless grapes. In both cases we mixed $CaSO_4$ with the wine at rates of 0, 1, 2, 4, 8, 16 and 32 grams of C.P. $CaSO_4$ per 1000 c.c. After standing for one week to reach an equilibrium the wine had pH values of 3.60 (untreated wine), 3.50, 3.45, 3.45, 3.45, 3.45 and 3.45 respectively. In other words the effect was slight and there was no further decrease in pH when more than 2 grams of $CaSO_4$ per liter was added.

The same amounts of $CaSO_4$ were added to portions of fresh Thompson seedless juice of 24.25° Balling, and the juices were fermented with Jerez yeast number 5. After fermentation was complete the pH values of the wines were found to be 3.8 for the untreated, and 3.7, 3.45, 3.35, 3.25, 3.20 and 3.20 for additions of 1, 2, 4, 8, 16 and 32 grams of $CaSO_4$ per liter respectively. The corresponding total sulfates as K_2SO_4 were: .032 (untreated), .19, .29, .39, .44, .34 and .46 grams per 100 c.c. respectively. The treated samples cleared more rapidly after fermentation, and their sediments were much more compact than those of the untreated. Addition of more than 8 grams of $CaSO_4$ per liter of juice, about 7 pounds per 100 gallons, had little additional effect on the pH. Seven pounds per 100 gallons would be about 14 pounds per ton of crushed grapes, if added before pressing.

For commercial conditions probably 5 grams per liter, about 4.2 pounds per 100 gallons of must, or about 8.4 pounds per ton of crushed grapes would be sufficient. It must be added to the must, not to the wine.

It is likely that the use of $CaSO_4$ in the making of Spanish type sherries in the United States would require modification of Regulation 7 of the Bureau of Internal Revenue. In the past the maximum limit set on sulfate content of wines by the Food and Drug Regulations was 0.20 grams K_2SO_4 per 100 c.c. This limit is at present under consideration for revision upward in the case of flor sherry, and no maximum is mentioned in the current edition of the Regulations. We are convinced that the plastering of musts for making of flor sherries is desirable and sound, although not essential if replaced by acidification with tartaric or citric acid.

WINERY EXPERIMENTS

In order to supplement our laboratory data on the utilization of flor yeasts, and to determine the feasibility of producing Spanish-type sherries by modification of the Spanish procedure, experiments were conducted in several California wineries, beginning in 1937. Some specific points

investigated were: changes in composition; rates of aging in containers of several sizes; control of acetification; aging after fortification.

Several of the experiments are still under way, but most of the experimental sherries have been aged sufficiently for bottling and judging. Three wineries have now undertaken to make flor sherries commercially. Therefore, reporting of the data at this time appears to be justified.

The results of the experiments on the whole were satisfactory. The unsuccessful experiments were very valuable in that they indicated what steps must be taken to prevent acetification. The experiments are reported under the names of the wineries in which they were conducted.

Summary

Following is a summary of our conclusions from these experiments.

Flor sherries were made successfully in fifteen different wineries, in 40- to 20,000-gallon lots, using 50-gallon barrels, sherry butts and 1500-gallon tanks and ovals. In most of these experiments a single-stage procedure was followed, wherein wine was held under film until a strong flor flavor and bouquet had developed, and then racked. Samples were fortified and bottled, and the remainder blended.

At least two years, and usually three, under film were necessary to develop sufficient flor character. However, in experiments in which only half the wine was removed at two to three years, and that replaced with one-year-old wine, a second harvest could have been made in six to twelve months. Such a modified solera would permit continued operation for an indefinite number of years. This procedure was followed successfully in two experiments, and is recommended in preference to the single-phase process.

Wine which had been aged before inoculation with flor film developed satisfactory flor character in two years, whereas new wine aged under film in the same cellar required 3 to 3½ years to develop full flavor and bouquet. Use of aged or partly aged wine in making flor wine is therefore recommended.

Under winery conditions, acetification occurred in several experimental wines of 14 to 15 per cent alcohol, but not at or above 15.5 per cent. The Spanish recommendation of a lower limit of 14.5 per cent is therefore too low for California conditions.

A moderate addition of SO_2 held lactic bacteria in check in two winery experiments in which they appeared, but failed to permanently halt acetic bacteria in wines of low alcohol content. Increase of alcohol to 15.5 per cent or above is recommended for wines inclined to acetify.

Aging after final fortification was best done in well-filled, closed containers to avoid oxidation with consequent browning of color and loss of flavor and bouquet. Such aging removes or reduces any harshness of odor and flavor. Baking destroys flor character.

Fining with highest quality casein was used to remove excess color from experimental sherries, and was preferred to decolorizing carbon, which affected the flavor. Bentonite clarification gave good results for wines already of satisfactory color.

Tastings by individuals and by groups indicated that several of the experimental sherries were very close to the better imported Spanish sherries in color, flavor and bouquet. They were usually somewhat lacking in the after-taste, which we believe is due to long contact with autolyzing yeast sediment in Spanish soleras.

Concannon Vineyards

The general plans of the various experiments conducted in California wineries, and the results obtained, were similar. Therefore, a detailed description of one such experiment is given, and the data for the other experiments are only briefly presented.

At the winery of the Concannon Vine-

yards near Livermore ripe Palomino grapes grown in the company's vineyard were picked, crushed and pressed on September 20, 1937. To the juice, which was of 24.5° Balling, were added 150 p.p.m. of SO_2 and a starter of Jerez yeast 5. In a week fermentation was nearly complete, the Balling being at that time –0.9°.

The new wine was racked 8 days later and again at 31 days. At the second racking a 50-gallon barrel was filled about four-fifths full, and inoculated with Jerez yeast 5 film. A loose cotton plug was inserted in the bung hole. As the nights had become cold at this time the barrel was placed in the boiler room. The new wine had 13.4 per cent alcohol, 0.62 grams of total acid, 0.067 grams of volatile acid, 0.013 grams of reducing sugar, 2.0 grams of extract (per 100 c.c.) and 79 p.p.m. of SO_2.

Three months after inoculation there was a slight odor of acetic acid and the microscope revealed a considerable number of acetic bacteria. Therefore, the SO_2 was increased to 180 p.p.m. and more Jerez yeast 5 film added. However, by June, 1938, the volatile acid had increased to 0.090 grams per 100 c.c.

Sherry material of 19 per cent alcohol was then added to bring the alcohol content to 15 per cent and the wine was moved to a cooler location in the main cellar. By July 18, 1938, the film was again vigorous and the volatile acidity had decreased to 0.062 grams per 100 c.c. After 22 months under film the wine was very pale in color and possessed a pronounced flor wine flavor and bouquet. A sample was fortified at the University and stored in bottles.

That stored in a partly filled gallon jug became brown in color and lost much of its flor wine character in six months; that stored in well-filled bottles remained pale in color, retained its flor character, and improved in smoothness of flavor.

This experiment, as did several other winery experiments, indicated that SO_2 cannot be relied upon to hold vinegar bacteria in check, and that a much safer preventive measure is that of increasing the alcohol to a level (15.5 per cent or greater) at which vinegar bacteria cannot grow.

Louis M. Martini

An experiment similar to that made at the Concannon winery was conducted at the L. M. Martini winery in Kingsburg in 1937 and 1938. A blend of juices from Malaga and Sultana grapes was brought to 25° Balling by the addition of grape concentrate. After completion of fermentation with Jerez yeast 5 and racking, the wine was stored under Jerez yeast 5 film for only about 7 months, a much shorter time than was desired, owing to unfavorable summer temperature. Its flor flavor and bouquet were much less pronounced than those of the Concannon wine, although a fortified sample possessed considerable flor character. During storage under film a few lactic bacteria made their appearance, but after addition of 150 p.p.m. of SO_2, fining with bentonite and reinoculation with flor film, the bacteria did not reappear. In other respects procedure and results were similar to those of the Concannon experiment.

In 1940 about 9,000 gallons of one-year-old wine in a 10,000-gallon tank were held under flor film for more than a year before blending with sherry material. It attained only a slight flor character.

One-year-old Palomino wine inoculated with flor film and stored in Spanish sherry butts in the company's cellar near St. Helena for three years or longer, developed pronounced flor bouquet and flavor.

In the same cellar similar wine stored in three 5,000-gallon tanks to a depth of about 18 inches under flor yeast film developed very rapidly and was ready to fortify at six months or less, but it possessed a noticeably yeasty flavor and bouquet. After half of the wine was removed and replaced with fresh one-year-old

wine, the blend was ready to fortify in about three months' time. However, the flor character of the wines made by this procedure was marred by a strong yeasty bouquet and flavor at time of removal from the tanks. By proper regulation of the depth of the wine and air supply it is possible that more favorable results can be obtained, since very satisfactory results were achieved in the Cresta Blanca experiment with 1500-gallon tanks. All experiments in the St. Helena winery of the L. M. Martini Company have been conducted by L. P. Martini.

Cresta Blanca Wine Company

An experiment begun in September, 1920, with two barrels of juice of 25° Balling was conducted at this company's winery near Livermore in a manner very similar to that previously described for the Concannon experiment. Some acetification occurred at 14.5 and 14.7 per cent alcohol, but was arrested by increasing the SO_2 content. One of the wines was under film 20 months and the other 30 months. Both developed pronounced flor character.

Another experiment was begun in July, 1943, on a larger scale with 1942 white wine in used sherry butts from Spain, stored in an open yard. Although inoculated several times with Jerez flor yeast film the butts of wine developed no film, evidently because the temperature in the head space was too high (90–100° F on a sunny day in March, 1944). When transferred indoors in April, 1944, and reinoculated, they developed a heavy film. At that time additional butts of white wine of the 1943 vintage were inoculated. Also, similar wine in eight 1500-gallon tanks and three 1500-gallon ovals, each containing about 1400 gallons of wine, was inoculated. Good films developed on all of the wines in tanks and ovals and in most of the butts. The alcohol content ranged from 14.2 per cent to 16.15 at the beginning of the experiment.

The wine in one oval acetified to 0.165 grams per 100 c.c. volatile acidity, and that of less than 15 per cent alcohol in two ovals also became vinegar sour. Other lots remained normal or low in volatile acidity. During storage under film there was some increase in alcohol content.

The experiment was terminated after the wine had been stored under film about 31 months, at which time the wines in the butts had developed pronounced flor character, and those in the 1500-gallon tanks appreciable and readily recognizable flor flavor and bouquet. They were blended with other sherry material. Unfortunately the blend was baked by the company and consequently lost all of its flor wine character.

Analyses made of most of the wines near the end of the experiment in 1946 gave the following averages:

	Alcohol (% by volume)	Total Acid (gms. per 100 c.c.)	Volatile Acid (gms. per 100 c.c.)	SO_2 (p.p.m.)
Butts....	15.9	.68	.054	90
Tanks....	15.2	.50	.042	115

Samples fortified at the end of the experiment in January, 1947, and stored at the University have developed satisfactorily.

Solano Winery

Six 50-gallon barrels of 1940 Palomino wine of 15 per cent alcohol were inoculated with the film stage of Jerez yeast 5, and six with that of Chalon yeast 12, in November, 1941. Film formation was heavy on all the wines, and pronounced flor flavor and bouquet developed in about 15 months. At 23 months, when the experiment was terminated, they were considerably past their optimum. However, samples fortified and stored at the University in Berkeley lost their earlier off-flavor, and after acidification developed into satisfactory flor wines.

The sample made with Chalon yeast was somewhat superior to the Jerez

sample in flavor and bouquet. Both wines were richer in flor character than most of our other experimental wines, and hence were very useful in making blends.

The initial total acidity at the beginning of the experiment was 0.40 and at the end it was 0.26 grams per 100 c.c. A similar decrease occurred in volatile acidity. In most other winery experiments there was also considerable decrease in these constituents, confirming data from laboratory experiments.

B. Cribari and Sons

The experiments with flor yeasts were conducted at the company's winery in Madrone, Santa Clara County, in 1937 and 1938. We were not sufficiently well acquainted with the importance of high alcohol content of the base wines at that time, and in one experiment used three barrels of wine of only 12.6 per cent alcohol. In spite of heavy initial film formation, acetification promptly set in. Addition of 100 p.p.m. of $S0_2$ on two occasions, and increase of alcohol content to 14.7 per cent by addition of sherry material, arrested acetification only temporarily. Three barrels of wine vinegar were eventually obtained.

In a second experiment the alcohol content of one barrel of new wine was increased to 13.7 per cent, and of another to 15.5 per cent before inoculation with flor film. The wine of 15.5 per cent matured normally; that of 13.7 per cent became vinegar sour in spite of addition of 100 p.p.m. of SO_2.

Wente Brothers

The experiment in this winery, located near Livermore, is of interest because half of the contents of a 50-gallon barrel of Burger wine was removed after being held under flor yeast film for 19 months and was replaced with an equal amount of one-year-old Green Hungarian white wine. After 10 months under film the blended wine was again ready to fortify, indicating that a modified solera might prove practicable. A sample of the Burger was fortified after 19 months under film and of the blend at 10 months. Both samples possessed very satisfactory flor wine flavor and bouquet.

Novitiate of Los Gatos

In this winery one experiment was conducted in 1937–1939 with three barrels of well-aged dry Sauterne wine of high SO_2 content (over 300 p.p.m.) and of 13.6 per cent alcohol. No growth of film occurred during the first six months after inoculation, and an additional six months was required after reinoculation for formation of a satisfactory film. Evidently the high SO_2 inhibited film formation. A sample from one barrel was fortified after 10 months under film and from the other two after 20 and 24 months. The last two wines developed pronounced flor character.

In other experiments several barrels of fresh juices of Chasselas doré and Clairette blanche grapes were fermented with flor yeast in 1937 and 1938, racked, inoculated with flor yeast film, and aged under film 3 to 3½ years. At least three years under film in 50-gallon barrels in the rather cool Novitiate cellar were required for satisfactory development of flor character. As the aged dry Sauterne required only 20–24 months under film for like development in the same cellar it would indicate that the use of aged or partly-aged wine in making flor wines might be advantageous. The experiment in the Wente winery also supports this suggestion.

In the second experiment acetification of one wine occurred at 14.9 per cent alcohol and of another at 15.2 per cent, indicating that some acetic bacteria can grow at exceptionally high alcohol content. This makes it advisable to use base wines of at least 15.5 per cent alcohol content for flor sherry production in California. The Spanish recommendation of 14.5 per cent is too low for local winery conditions.

Inglenook Vineyard Company

Two experiments were conducted at this winery in the Napa Valley. In the first experiment, begun in February, 1938, one-year-old Palomino wine of 14.4 per cent alcohol in three 50-gallon barrels was inoculated with Jerez yeast 5 film. The wines increased in volatile acidity in six months to 0.114, 0.106 and 0.090 grams per 100 c.c., but when the alcohol content was then increased to 15.3–15.6 per cent by addition of sherry material, and the wine reinoculated, the volatile acidity decreased and eventually dropped to 0.036, 0.036 and 0.054 grams per 100 c.c. respectively. The alcohol content increased slightly during aging. At 27 months the wines had developed very satisfactory flor character.

In the second experiment four used Spanish sherry butts of one-year-old Palomino were stored under film from March, 1942, until January 10, 1947. The initial alcohol contents were 16.3, 15.9, 15.9 and 15.7 per cent; the final, 16.75, 16.00, 15.75 and 16.00 per cent, a moderate increase in about five years.

The wines developed very satisfactory flor flavor and bouquet and samples fortified and stored in glass at the University have retained this character very well.

These two experiments illustrate the principle that the smaller the container the more rapid is the development of flor character under film. The wines in the 50-gallon barrels required only 27 months; those in the butts about 60 months. Possibly, however, other factors, such as initial alcohol content, may have been involved. Another interesting observation was that the three barrels in the first experiment were stored on an upper floor of the winery near the roof during the first summer. Film growth was excellent during the winter and spring but all of the film dropped and was absent during the summer because of the high temperature. It reappeared in the fall, confirming common experience in Spain.

Italian Swiss Colony

This experiment was begun February, 1939, in the Colony's Asti plant. A blend of 15.8 per cent alcohol of Palomino wine and fortified sherry material was placed in twenty used Spanish sherry butts and inoculated with Jerez yeast 5 film. About two and one-half years later half of the contents of each butt was drawn off, blended and stored unfortified. It was replaced with wine of 15.4 per cent alcohol.

At irregular intervals during the ensuing five and one-half years about half the contents of each butt was removed, blended and stored unfortified. The alcohol content of the wines in the butts was above 16 per cent during most of the experiment, several being at 16.7 per cent, yet film growth and activity were good.

The experiment was terminated in January, 1947, about eight years after its beginning, because of construction operations. All of the wines were in excellent condition at that time, indicating that this modified solera might have been continued indefinitely. Because of the high alcohol content no difficulty was encountered with acetification.

The two blends of unfortified wines drawn from the butts during the experiment were sampled in April, 1948, and found to possess pronounced flor flavor and bouquet together with considerable of the characteristic after-taste of Spanish sherries. Samples were fortified and stored at the University.

Other Experiments

Experiments at the Petri Winery, at Escalon, and Bear Creek Winery, at Lodi, with 5,000-gallon tanks of white wine under flor film are being conducted in cooperation with the winery chemists, but development of flor character is extremely slow in these large containers. Similar experiments made in three other wineries with large tanks of wine also show that development of flor character in large volumes of wine is very slow.

Such large quantities of wine under film seem impracticable or at least not advantageous.

However, the experiments with 1500-gallon tanks of wine at the Cresta Blanca winery and in one other plant demonstrated that flor character can be developed at a moderate rate in such tanks.

Effect of Baking

When our experiments were first begun it was common belief among California wine makers that sherries were naturally baked in casks in the sun in Spain. Consequently, we baked several small lots of about one gallon each of our first experimental flor wines at 120° F. and at 140° F. In all cases the color darkened very much, the wine lost all or nearly all of its flor flavor and bouquet, and acquired the usual caramel-like flavor of baked wines.

In 1947 a blend of experimental flor sherry and commercial sherry material was baked at the customary temperature by a large winery. The baked wine lost all flor character.

A Laboratory Solera

To test further the practicability of a modified solera we filled two 10-gallon barrels about four-fifths full of one-year-old dry Palomino wine of 15.5 per cent alcohol from the Solano winery. On November 26, 1941, we inoculated one with Jerez film 5, the other with Chalon 12. Both were plugged loosely with cotton and left at laboratory temperature, about 65–72° F.

On April 22, 1942, both wines had developed pronounced flor sherry character. Half of each was removed and replaced with fresh Palomino wine of 15.5 per cent alcohol without disturbing the films. Withdrawal of half of the contents was repeated on December 30, 1942, August 11, 1943, November 15, 1943, and April 15, 1944. There was little difference in color, bouquet, and flavor between the Jerez and Chalon wines, although the Chalon was noticeably more pungent in bouquet. At present, after four years aging in bottle, both wines have very similar, and very satisfactory color, flavor, and bouquet.

Fining and Stabilizing

As mentioned in the introductory section of this publication, sherry wines in Spain are fined (clarified) with egg white and Spanish clay.

We fined our experimental wines with a 5 per cent mixture of powdered bentonite in water, beaten up thoroughly until smooth. The suspension was allowed to "cure" by standing a week before use.

To clarify the wines, 15–20 c.c. of the bentonite mixture was added to each 1000 c.c. of wine; or from 1.5 gallons to 3.0 gallons per 100 gallons of wine, corresponding to about 6 to 8½ pounds of powdered clay per 1000 gallons of wine. The wine and clay suspension were mixed thoroughly and allowed to settle. Usually, lots of one to five gallons of wine had settled brilliantly clear in two to three days. In commercial practice fining with bentonite or other fining agent, or filtration, would be utilized; or perhaps both fining and filtration.

At present, both in the United States and Great Britain, the principal demand in imported Spanish sherry is for the pale dry, that is, the *fino*, *amontillado* and *manzanilla* types. Sherry tends to darken and become amber to brown in color. We found that the color of our flor wines could be readily bleached to any desired tint by use of casein as a fining agent. While decolorizing carbon accomplished the same objective it left a disagreeable flavor in the wine. We found that about 10 c.c. of a 2 per cent casein solution per liter for wine of medium amber, and about 20 c.c. for one of dark amber to brown color gave satisfactory lightening of the color. With the casein we also used bentonite as previously described. We prepared the casein by dissolving the soluble type in water to give a 2 per cent solution.

The experimental wines were not flash pasteurized to coagulate certain colloids and to sterilize them, nor were they refrigerated for detartration. In commercial practice both of these operations would probably be applied. No doubt also it would be necessary in some cases, as with other wines, to treat flor sherries to remove traces of heavy metals such as copper and iron. Fortunately our experimental wines did not require this treatment.

Experimental Sherry Blends

The sherries from our various experiments differed considerably in bouquet, flavor and color. Therefore we made various blends in which the proportions of several sherries were varied to more nearly approximate the character of imported Spanish *fino* and *amontillado* sherries. One very satisfactory blend consisted of 3000 c.c. of sherry from the Solano winery experiment, 1000 from the Wente winery experiment, 1000 from the Inglenook winery experiment, 1000 from the Concannon winery experiment and 300 c.c. of experimental flor sherry that had stood on a large volume of flor film lees for a year. The last named was used to impart some of the typical after-flavor of Spanish sherry.

The blends were made to about 0.50 grams total acidity per 100 c.c. by addition of citric acid, as all were below this acidity. The sugar content was raised to 1.25 to 1.60 grams per 100 c.c. by addition of invert syrup in most of the blends to approximate that of a pale, dry Spanish sherry.

All of the experimental wines used in the blends were samples fortified in the laboratory and aged at least one year after fortifying, in most cases two to four years.

Tastings of Experimental Sherries

During the past ten years samples of our experimental sherries, particularly the better ones from winery experiments, have been tasted by many persons individually, or by groups of two or three persons, and several tastings by groups of ten to sixty persons have been held.

In a typical group or panel tasting three blends of experimental pale, dry sherries were tasted in comparison with a pale dry imported Spanish sherry, Duff Gordon Pinta. The samples were identified by number only. One of the objects of the tasting was to ascertain what proportion of a group of experienced wine makers and regular consumers of wines could identify the imported Spanish sherry. In one case, out of a total of 44 tasters, 18 properly identified the imported sherry and 26 were of the opinion that one or the other of the experimental sherries was the imported sherry. In other words, considerably less than half the group were able to select the Spanish sherry sample.

In bouquet and first effect on the palate the four sherries were very similar, but in after-taste the imported sherry carried the typical "propionic-acid-like" flavor in marked degree, whereas the experimental sherries had little of that peculiar after-taste of imported Spanish sherries. We believe the difference is due to the prolonged contact of wines in the Spanish soleras with the autolyzing film yeast sediment.

Two other tastings of these wines by groups of experienced wine makers and tasters gave a similar result.

Similar tastings by groups of advanced students and staff members resulted in less than half of the tasters identifying the imported sherry or sherries in tastings of four to six samples.

Where numerical scores were given by tasters the blends of experimental sherries were given ratings close to those given the imported sherries.

In general, our best experimental sherries, as one well-known sherry importer put it, "have the nose and foretaste of a *fino* but are somewhat lacking in aftertaste." We are inclined to agree with his appraisal.

RECOMMENDED PROCEDURE

The following outline of recommended procedure need not be followed in detail by the prospective commercial producer of flor sherries, but may be modified to suit the conditions in his cellar.

1. First, consult the local representative of the Alcohol Tax Unit of the Bureau of Internal Revenue concerning the recently promulgated special A.T.U. regulations for the aging of flor wines and their fortification.

2. Next prepare a starter of flor yeast in the film stage. Cultures with full directions for preparing a starter may be had from the Berkeley Yeast Laboratory, 3167 College Avenue, Berkeley. In brief, the procedure consists in inoculating a pint or half-pint bottle of sterile grape juice with a pure culture of flor yeast, fermenting, allowing a film to form on the fermented juice, inoculating several one-gallon jugs about three-fourths full of dry white wine of 15–16 per cent alcohol, and allowing the yeast film to develop in a room about 65–75° F. A strong, vigorous film should form in about three weeks.

3. To dry white wine of the Palomino variety or other variety of neutral flavor, and about one year of age, add unbaked sherry material of 19–20 per cent alcohol content to bring the blend to about 15.5 per cent alcohol (above 15 and below 16 per cent). Or arrange with the local A.T.U. representative to fortify the wine to about 15.5 per cent alcohol with high proof brandy. Analyze the wine for SO_2 and add SO_2 or bisulfite or metabisulfite to increase the SO_2 content to 150 p.p.m. During its previous cellar history the wine should have been stabilized by refrigeration at 24–26° F and made clear by fining or filtration. If the pH value is above 3.5 add citric acid to bring it to 3.1–3.3.

4. Place this wine in 50-gallon barrels, used imported Spanish sherry butts or winery puncheons. Leave a head space of about 20 per cent (i.e., fill about four-fifths full). Place absorbent cotton in the bung holes and store the barrels on skids or in racks in a room held at 65–75° F. See figure 4.

5. Inoculate the wine by pouring into the casks the contents of a gallon jug of the film yeast starter (previously prepared in step 2) in such a manner that a considerable amount of the film is added to each cask. A gallon jug of the starter is sufficient to inoculate four to six 50-gallon barrels or three to four butts or puncheons. Return the cotton to the bung holes of the casks. When film forms on the wine in the casks it may be used to inoculate other lots of wine.

6. Observe the appearance of the film and odor and taste of the wine once a month, and analyse the wines regularly for volatile acidity. At the same time examine samples from each cask under the microscope to detect any lactic bacteria. If such are found increase the SO_2 content of the affected cask of wine to 150 p.p.m. and fine or filter and reinoculate with flor yeast film.

7. The wine should develop satisfactory flor flavor and bouquet in 50-gallon barrels in 18–24 months or less and in butts or puncheons in about 3 years. When the wine is considered ready for fortification consult the local A.T.U. gauger and arrange for fortification. Draw off about half of the contents of each cask and blend the lots of like color, flavor and bouquet. Replace the wine drawn from the casks with one-year-old wine of composition and quality similar to those of the wine originally used.

Fortify the wine drawn from the solera casks to 19–19.5 per cent alcohol with neutral, best quality, high proof brandy, with coöperation of the local gauger and in accordance with Federal regulations. If California State regulations would permit it, fortification to only 18 per cent alcohol would give a superior product.

8. Add stabilized Angelica of neutral

Fig. 10. Flor sherry aging in a California wine cellar. (L. Martini, Jr.)

flavor and pale color to increase the total reducing sugar content to about 1.5 grams per 100 c.c. for a dry sherry and to 3–5 grams per 100 c.c. for a medium sweet sherry. Titrate a sample, and if total acidity is found to be below 0.50 grams per 100 c.c., add citric acid to increase it to that level.

9. Store in completely filled and tightly-sealed, well-seasoned oak casks, such as Spanish sherry butts, in a cool cellar for several months in order to permit amelioration of the flavor of the added high-proof brandy and mellowing of the flor yeast flavor and bouquet.

10. Rack. Fine with bentonite, or if the color is too dark, with water-soluble casein and bentonite or filter. The casein may be added as a 2 per cent solution in water and the bentonite as a 5 per cent suspension (thin mud) in water. The casein is prepared immediately before use and the bentonite at least a week before use. Approximately 1–2 gallons of the casein solution and a similar amount of the bentonite suspension is usually required for each 100 gallons of wine.

11. Finally, give the wine a polishing filtration and bottle it.

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Table 7. EFFECT OF pH VALUE OF THE WINE ON THE ACTIVITY OF FLOR FILM YEAST.

Time in Days	Volatile Acidity at Various pH Values						
	3.95	3.60	3.36	3.20	3.00	2.85	2.65
0	.066	.066	.066	.066	.066	.066	.066
14	.024	.024	.030	.030	.030	.036	.066
19	.015	.018	.021	.021	.021	.027	.066
26	.014	.015	.012	.015	.015	.018	.060
47	....	....	....	....	....	....	.024

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